LEVEL II

Research Memorandum 78-6

PREDICTING TANK GUNNERY PERFORMANCE

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U. S. Army
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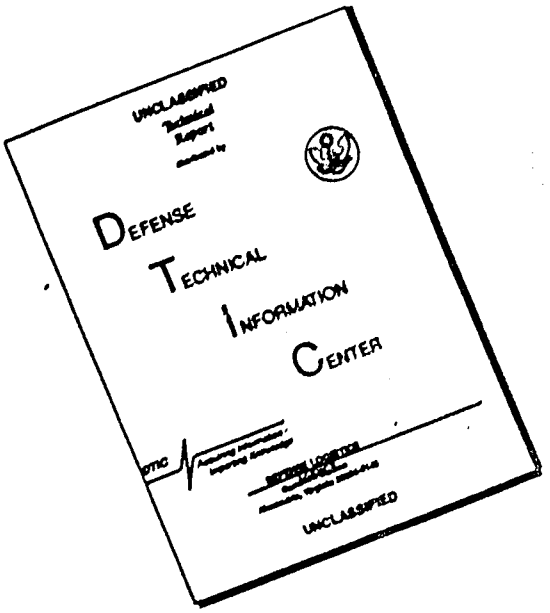

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9 Research Memorandum 78-6

6 PREDICTING TANK GUNNERY PERFORMANCE

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PREDICTING TANK GUNNERY PERFORMANCE

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INTRODUCTION

While much military research effort has been expended in the measurement of aptitudes and the determination of the relationship between these measures and future (or concurrent) performance on a myriad of other military tasks, relatively little concentrated work has been done with Armor tasks. Vast changes have been proposed for Armor (Tank Force Management Group, 1976) including increased emphasis on Armor in the combined arms, a new family of more complex Armor weapon systems, and expanded individual performance requirements. A more thorough knowledge of the aptitudes and skills prerequisite to effective performance has become necessary for the proposed Armor selection/assignment systems. The purpose of this research was to expand our knowledge of the relationships between selected aptitudes and tank gunnery performance. Three sources of information served as the primary bases for this research: (1) Kaplan's work with the Army Flight Aptitude Selection Battery-FAST (Kaplan, 1965); (2) Thomas and Sternberg's recommendations for a selection battery for Armor crewmen (Thomas and Sternberg, 1964); and (3) recent work in skill/aptitude measurement and Armor performance prediction (Greenstein and Hughes, 1977, and Hughes, 1976 a and b). This work drew heavily on (3) and is best thought of as a continuation of the Greenstein/Hughes effort.

Greenstein and Hughes tested trainees in Advanced Individual Training, Armor (AITA) and 11E (Armor MOS) personnel using instruments taken from Kaplan's FAST and skills tests common to armor training. In analyzing their results they observed numerous statistically significant individual relationships between aptitude or skill scores and several of the available measures of Armor gunnery performance. In addition, Hughes developed composite aptitude scores, based on a factor analysis of 10 of the instruments. These were used to predict Burst-on-Target (BOT) performance (an important skill in tank gunnery) and yielded a significant positive multiple correlation.

These research efforts provided suggestive evidence of numerous relationships between aptitude/skill measures and Armor gunnery performance. Greenstein and Hughes suggested, however, that extensions of their work were needed because of the limitation in the scope of their initial efforts. Their predictors were often derived from the performance of relatively small samples of men. In addition, they were tested against pre-qualification gunnery performance due to the nonavailability of a Tank Crew Qualification Course (TCQC-Tank Table VIII) on Ft Knox at the time they conducted their research. Finally, several ostensibly important intermediate performance criteria, such as performance on the Field Mini-Tank Range Complex (FMTRC, TC 17-12-6), were not available to them at Ft Knox.

From these previous efforts, questions arose regarding whether aptitude-performance relationships observed for AITA trainees and Ft Knox 11E personnel were generalizable to a large sample of gunners actually assigned to duty in an operational Armor TO&E unit, and whether the relationships previously observed could be fruitfully extended to other crewmen and other skills in such a unit. Further research in a TO&E unit could determine whether the parsimony obtained through the use of composite scores by Hughes could be extended to prediction of performance on actual main-gun tank gunnery tables. It would also provide the opportunity to gain insight into the potential for analogous prediction of Tank Commander's performance by evaluating their aptitude test and composite scores against performance on Table VIII.

Findings from this research may be useful in the development of predictive test batteries for gunner's and tank commander's performance and may indicate to what extent composite scores are related to both the actual gunnery performance of gunners and tank commanders. Further, the relationship between performance of intermediate tasks (such as the FMTRC) and final gunnery performance will be determined. That information may indicate the utility of selecting or retaining gunners or tank commanders based on their performance on such intermediate tasks, an informal practice in relatively widespread usage.

Driver performance has thus far not been mentioned because in the past it has been seen as having relatively little impact on Tank Crew Qualification Course scores. Most engagements are fired from a designated tank trail with the firing tank stationary. Nevertheless, emerging Armor doctrine requiring tactical driving and shoot-on-the-move techniques places great emphasis on driver job performance. With the introduction of AOS (add-on-stabilization) to the current line of M60A1 tanks and the fielding of the new XM-1 in the 1980's, such techniques will most likely be increasingly emphasized and evaluated on the Army's Tank Crew Qualification Courses. Pilot research by Greenstein and Hughes (1977) and Hughes (1976) has indicated some potential for predicting driver performance. This research, therefore, included a driver performance ranking as a criterion of driver proficiency.

SPECIFIC OBJECTIVE

The specific objectives of this research were to evaluate the relationship between gunner's and tank commander's: (1) scores on a series of potentially predictive paper-and-pencil tests and main-gun Tank Table performance; (2) intermediate tank gunnery training task performance and main-gun Tank Table performance; (3) composite scores and their performance on the main-gun Tank Tables; and (4) to evaluate the relationship between aptitude test scores and driver performance as measured by driver's ranking within their platoon.

METHOD

SAMPLE

Subjects were the Tank Commanders (TCs), Gunners (Gnrs), and Drivers (Dvrs) in a TOE Armor Battalion undergoing annual tank gunnery training and qualification. Data were collected on a total of 51 TCs, Gnrs, and Dvrs.

PROCEDURE AND VARIABLES

The research was conducted in two phases. In the initial phase, ARI personnel administered six paper-and-pencil aptitude tests to the TCs, Gnrs, and Dvrs under standard classroom conditions. The tests included in the battery are listed in Table 1 (items 1-6). This battery included tests designed to measure an individual's aptitude for recognizing or memorizing complex visual patterns (Visual Recognition and Visual Memory), discriminating the similarity or difference between letter/number/symbol patterns (Lateral Perception), determining locations from visual cues presented in photographs (Locations), exactly perceiving and reproducing a geometrical pattern (Patterns), and rapidly locating, in succession, numbers presented in varying sizes, locations and orientations (Speed of Perception).

During the following three weeks the men were tested on a number of skills tests comprising the intermediate gunnery criteria. Preparation for and completion of these tests is routinely required during the initial phases of annual tank gunnery training (see TC 17-12-5 and 17-12-6). The skills tests administered to men in the two crew positions of Gnr and TC are shown in Table 1 (items 12-18), and are described below.

The Willey BOT trainer is a device which permits the evaluation of a gunner's skill in correctly superimposing a simulated sight reticle on a tank target outline using simulated gunner's hand controls, and correcting initial lay through feedback of information on first-round miss. The device provides a high degree of fidelity. The mean lay time (for 12 exercises) and number of hits following application of the BOT technique were the dependent variables of interest.

The Field Mini-Tank Range Complex (FMTRC) is a subcaliber tank range utilizing .22 cal rifles mounted on the gun tube of standard M60 tanks. After the .22 cal rifle and tank sights have been properly adjusted, a gunner can practice firing on stationary and moving miniature targets on a sand table. This provides realistic BOT experience and practice in tracking moving targets. All Gnrs received day and night

Table 1

PREDICTOR VARIABLES

Tests for Hughes' Composite Scores	Position Evaluated		
1. PT 5088, Lateral Perception	TC	Gnr	Dvr
2. PT 2852 (R), Locations Test	TC	Gnr	Dvr
3. PT 2788 (R), Patterns Test	TC	Gnr	Dvr
4. PT 5087, Visual Memory Test-ARL	TC	Gnr	Dvr
5. PT 5086, Speed of Perception-ARL	TC	Gnr	Dvr
6. PT 5089, Visual Recognition Test	TC	Gnr	Dvr
Additional Paper-and-Pencil Tests			
7. PT 3129, Mechanical Ability Test	TC	Gnr	Dvr
8. PT 2853, Object Completion	TC	Gnr	Dvr
9. PT 4489, Attention to Detail	TC	Gnr	Dvr
Hughes' Composite Scores			
10. Unlabelled (Variables 2, 3, 4)	TC	Gnr	
11. Unlabelled (Variables 1, 5, 6)	TC	Gnr	
Intermediate Armor Gunnery Performance Measures			
12. FMTRC[a], percent hits on stationary targets		Gnr	
13. FMTRC, percent hits on moving targets		Gnr	
14. Willey BOT[b], mean time of BOT		Gnr	
15. Willey BOT, percent BOT hits		Gnr	
16. TCGST[c], main-gun laying, mean time	TC		
17. TCGST, ranging on target, mean time	TC		
18. TCGST, ranging on target, mean error	TC		
Criterion Variables			
19. Tank Table V, percent 1st round hits		Gnr	
20. Tank Table VIII, number successful stationary precision engagements	TC		
21. Tank Table VIII, time on stationary precision engagements	TC		
22. Tank Table VIII, number successful stationary battlesight engagements		Gnr	
23. Tank Table VIII, time on stationary battlesight engagements		Gnr	
24. Tank Table VIII, total crew score	TC	Gnr	
25. Driver's ranking			Dvr

[a]Field Mini-Tank Range Complex, TC 17-12-6
[b]Willey Burst-on-Target Trainer
[c]Tank Crew Gunnery Skills Test, TC 17-12-5

training on FMTRC Tables I-IV, VI and VII, according to TC 17-12-6. Also included was an additional 20-round day moving target Table (VIIa) following Table VII. Measurements used in this research were percent hits on Table IV (stationary target) and VII (moving target) because these were free of warm-up effects and provided the most stable performance measures.

Tank commanders were evaluated on their performance in laying the main-gun on a target, and their speed and accuracy in ranging. In all types of main-gun engagements, the TC has the responsibility for "gun-laying", traversing the turret and orienting the main gun toward the target so that his Gnr can identify the target in his vision blocks and lay his sight reticle on the target in preparation for firing. In "precision engagements", which are used when engaging targets at a distance (where accurracy is emphasized), the TC is responsible for using his coincidence range finder to determine range to the target. The TC skills test variables were the mean time required to lay the main gun, the mean time to range on the target, and the mean ranging error. Twelve gun-laying and ranging exercises were conducted for each TC at ranges from 1124 m to 2514 m.

In the second phase of the research the Armor Battalion received their normal main-gun and automatic weapons training (TC 17-12-5) up to and including their final qualification Tank Table VIII. The criterion performance data on Table V (moving target, stationary tank) were collected by the battalion while Table VIII (TCQC) data were collected in conjunction with the Division Tank Gunnery Assistance Team. Table V provided hit/miss data while Table VIII data included both overall Table VIII scores and time/accuracy measures on individual engagements. Table VIII included a Day and Night phase, each with five two-round main gun engagements and five machine gun engagements. Due to the relatively few M60A1AOS tanks in the battalion, all main-gun engagements were fired with the firing tank stationary. In total, Table VIII included 4 precision stationary-target engagements, 4 battlesight stationary-target engagements, and two moving target engagements (one precision, one battlesight).

Performance criteria used for tank commanders were performance (time to first round and success) on main-tank-gun precision engagements against stationary targets (P-S engagements). Such engagements require a great deal of TC involvement in terms of both his physical performance requirements (gun laying and ranging) and supervisory responsibility. Also used were Table VIII overall scores, which incorporated the sum of all performance with main tank gun and machinegun engagements, because the TC has complete supervisory responsibility over the tank crew.

Criteria used for Gnrs were hit/miss on Table V (moving target) engagements, success and time on main-tank-gun battlesight engagements against stationary targets (BS-S engagements), and Table VIII scores.

Table V scores were used as a measure of ability to hit moving targets because Table V provided a more stable measure (based on 10 two-round engagements) than would Table VIII, which had only two two-round moving-target engagements. Battlesight engagements were chosen because these are primarily a Gnr's task and require a relatively small performance contribution from the TC. On these engagements, a fixed range setting is used; no TC ranging is required. Table VIII scores were chosen because the Gnr is involved in all major components of the total score.

The Dvr's criterion was the Dvr's ranking in the platoon (the mean rank assigned by the platoon sergeant and platoon leader). All criteria are shown in Table 1 (Items 19-25).

During the time between the initial testing and the final testing additional tests given by Greenstein and Hughes were found to be related to gunnery performance. These tests, also shown in Table 1 (Items 7-9), were administered immediately following Table VIII. They included a test of mechanical aptitude/achievement (Mechanical Abilities), ability to detect a partially obscured outline (Object Completion), and attention to small details--discriminating "C's" in a row of "O's" (Attention to Detail).

RESULTS

Of the 51 TCs in the battalion, complete aptitude test scores were collected on 38 (75%) TCs who completed Table VIII while complete skills test scores were collected on 40 (78%) TCs who completed Table VIII. Most losses occurred through reassignment; relatively few were due to replacement because of inability to perform the job. For purposes of statistical analyses, the attrition was considered to be random with respect to ability to perform. Thirty-eight (75%) of the Gnrs in the battalion completed all aptitude tests and Table VIII; usable firing records for only one of these men were not available for Table V. Of the 51 Gnrs, only 27 (53%) completed all skills tests and fired Table VIII. Some Gnrs were replaced due to reassignment, suspected inability to perform as Gnr, or replacement by new higher-grade men entering the companies. In addition, many who remained throughout the research were not tested on all skills tests due to leave, illness, etc. Again, the losses were treated as random occurrances. Finally, of the 51 drivers, 29 (59%) completed all aptitude tests. Losses were considered random here also.

The typical enlisted TC included in the analysis was an E-5 with 4 years service while the typical officer TC was an O-1 with 1 year of service. The typical Gnr was an E-4 with 2 years service while the

typical Dvr was an E-3 with 1 year of service. A rank/years service profile is included in Figure 1 for men in each position.

Despite the relative inexperience of the men in the battalion (as compared to a typical FORSCOM battalion) the unit performed very well on Table VIII. Of the four Armor battalions in the division, they were the high battalion. To facilitate comparisons of this battalion's performance with that of other battalions participating in this type of research in the future, selected summary data for the battalion's firing is provided in Appendix A. Means and standard deviations for Table V and VIII engagements, as well as a complete intercorrelation matrix, are included for 37 of the tanks in the analysis.

The analyses of the data collected in this research were conducted separately for men in each crew position with separate analyses for aptitude and skills tests. Crew position data were analyzed separately in order to predict performance for men in each position. The separate skills and aptitude test analyses were conducted for statistical reasons. Because many men who took all aptitude tests did not take all skills tests, and vice versa, the number of crewmen in each position with complete aptitude and skills test scores (20-25 per position), along with the larger number of predictors (9 aptitude tests plus 4-5 skills tests) would have produced an untenably small predictor to subject ratio of about 1:2.

The results are discussed in the following paragraphs. Results are given for TCs first, then Gnrs, and finally Dvrs. Within a crew position, aptitude test analyses are presented first, then skills tests (for TCs and Gnrs) and composite aptitude scores.

TANK COMMANDER'S APTITUDES AND SKILLS AS PREDICTORS

TC's paper-and-pencil tests (tests #1-9, Table 1) were scored and an intercorrelation matrix computed. Zero-order correlations and the multiple correlation were calculated for each of the three TC criteria: number of successful precision engagements, time on precision engagements, and Table VIII total score. Finally, the Wherry-Doolittle test selection technique (Garrett, 1953) was used to select the best subset of tests with each criterion. The Wherry-Doolittle technique produces a "shrunken R" to account for the proportion of tests to subjects used in its calculation. The zero-order correlations, multiple correlations, and Wherry-Doolittle selected tests and shrunken multiple correlation are shown in Table 2. Most interesting were the relationships between aptitude scores and success on P-S engagements. Not only was the multiple R significant but several of the zero-order correlations were also. A highly significant positive relationship was found between Object Completion scores and P-S success. In addition, the Wherry-Doolittle shrunken R

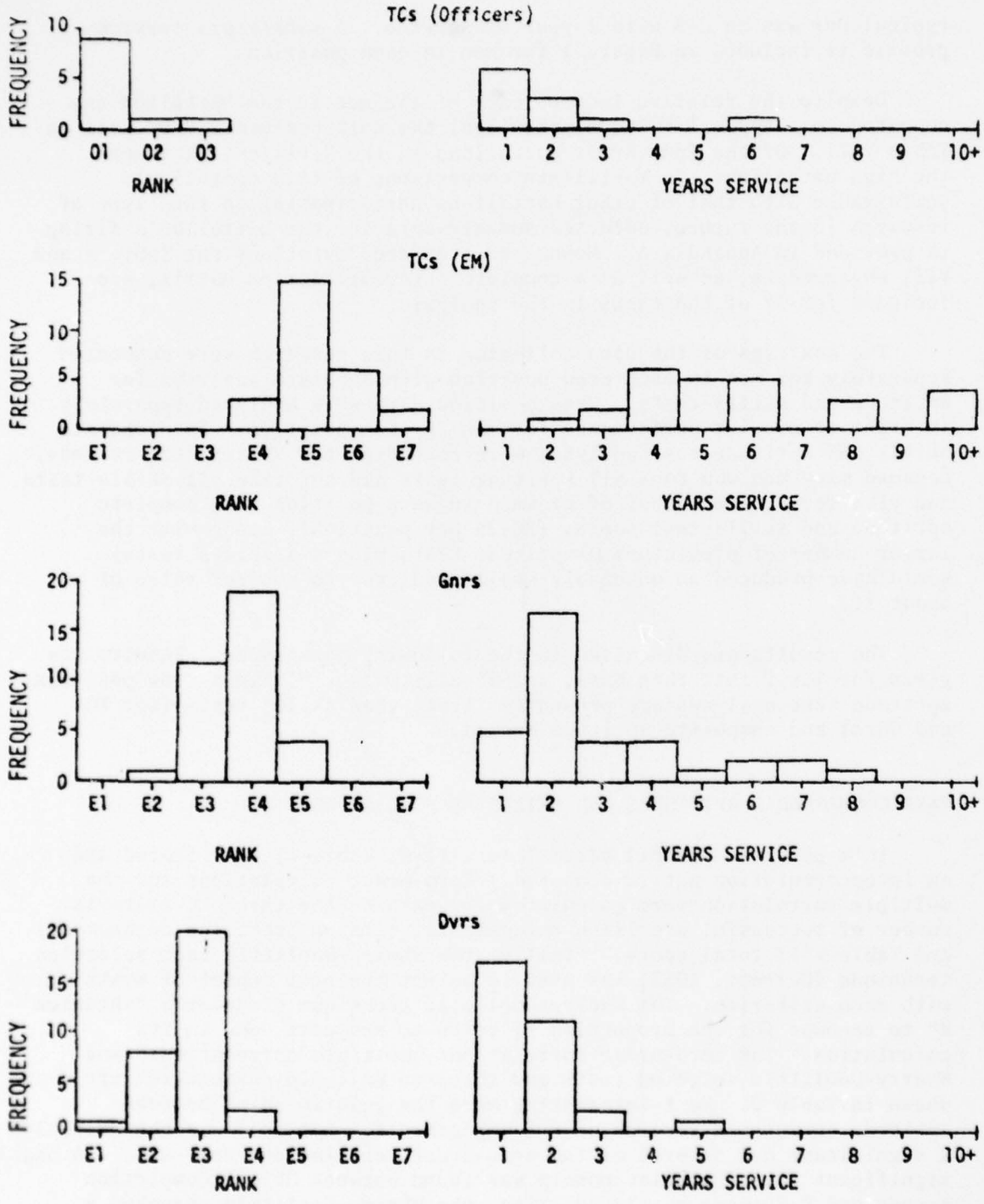

Figure 1. Rank and Years Service of Crewmen in Sample

Table 2

THE RELATIONSHIPS BETWEEN TC'S ABILITY TEST SCORES AND SELECTED MEASURES OF GUNNERY PERFORMANCE

Table VIII

Criterion: / Variable:	# Successful P-S Engagements	Time on[a] P-S Engagements	Total Score
Locations	+.17	+.08	+.13
Speed of Perception	-.06[b]	+.19[b]	-.21[b]
Lateral Perception	+.04	+.03	+.03
Visual Recognition	+.20[b]	-.11	-.02[b]
Visual Memory	+.21	-.03	-.02
Object Completion	+.49[b]***	+.05	+.14[b]
Patterns	+.30*	+.02	+.04
Mechanical Abilities	+.31[b]*	-.01	+.26[b]
Attention to Detail	+.12	-.17[b]	+.26
N =	38	38	38
Multiple R	.70**	.33	.57
Wherry-Doolittle Shrunken R (tests)	.56 (4)	.20 (2)	.42 (4)

* p < .10 2 tailed
** p < .05 2 tailed
*** p < .01 2 tailed

[a] Signs reversed because time and error measures are such that high scores indicate poor performance.
[b] Test selected by Wherry-Doolittle Technique.

of .56, based on four tests--Speed of Perception, Visual Recognition, Object Completion, and Mechanical Abilities--warrants attention. A plot of actual P-S success vs. expected P-S success, based on a regression analysis of the Wherry-Doolittle selected tests, is shown in Figure 2. The same four tests, when used as predictors of Table VIII score, yielded a significant R of .49 (not shown in Table 2) and were selected by the Wherry-Doolittle technique as the best predictors of Table VIII performance. The Wherry-Doolittle yielded a shrunken R of .42. A complete intercorrelation matrix for all instruments, including means and standard deviations, is shown in Appendix B.

An analogous procedure was used in the evaluation of TC's skills test scores. The zero-order, multiple, and Wherry-Doolittle correlations are shown in Table 3. Only two zero-order correlations are noteworthy, the relationships between ranging time and total score (where the longer the time the lower the score) and between gun-laying time and number of successful PS engagements (where the longer the time, the fewer successful engagements). A complete intercorrelation matrix for all TC's skills tests, including means and standard deviations, is included in Appendix C.

Table 3

THE RELATIONSHIPS BETWEEN TC'S SKILLS TEST SCORES AND SELECTED MEASURES OF GUNNERY PERFORMANCE

Table III

Criterion: / Variable:	Total Score	# Successful P-S Engagements	Time on[a] P-S Engagements
Gun Laying Time[a]	+.24[b]	+.37[b]***	+.06
Ranging Time[a]	+.26[b]*	+.10	-.23[b]
Ranging Error[a]	+.07	+.08	+.01
N =	40	40	40
Multiple R	.33	.39	.26
Wherry-Doolittle Shrunken R	.28	.37	.23
(tests)	(2)	(1)	(1)

* $p<.10$ 2 tailed
*** $p<.01$ 2 tailed

[a] Signs reversed because time and error measures are such that high scores indicate poor performance.
[b] Test selected by Wherry-Doolittle Technique.

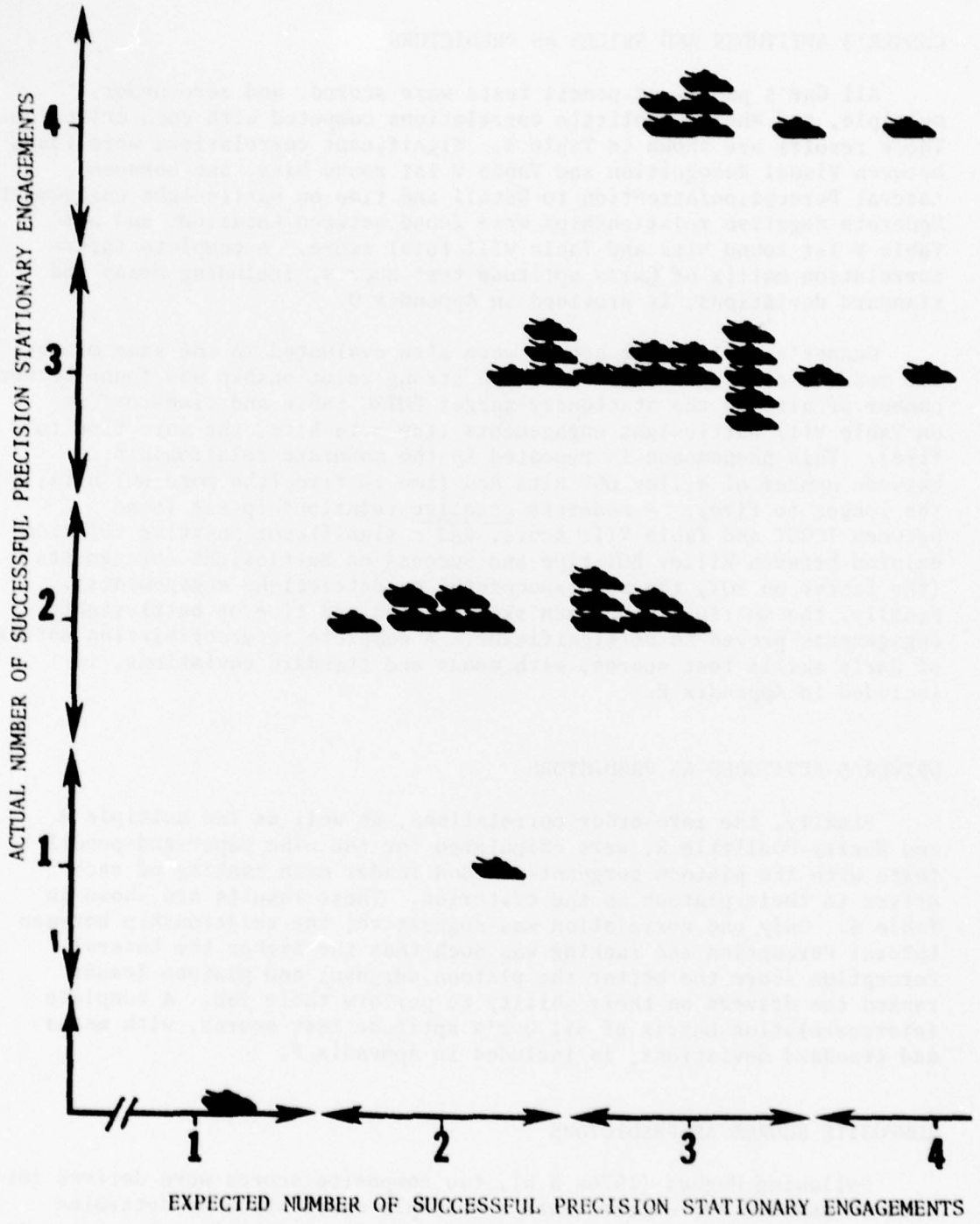

Figure 2. The Relationship between Actual Successful Precision Stationary Engagements and Expected Successful Engagements Based on Tank Commander's Abilities

GUNNER'S APTITUDES AND SKILLS AS PREDICTORS

All Gnr's paper-and-pencil tests were scored, and zero-order, multiple, and Wherry-Doolittle correlations computed with each criterion. These results are shown in Table 4. Significant correlations were found between Visual Recognition and Table V 1st round hits, and between Lateral Perception/Attention to Detail and time on battlesight engagements. Moderate negative relationships were found between Locations and both Table V 1st round hits and Table VIII total score. A complete intercorrelation matrix of Gnr's aptitude test scores, including means and standard deviations, is provided in Appendix D.

Gunner's skills test scores were also evaluated in the same manner. The results are shown in Table 5. A strong relationship was found between number of hits on the stationary-target FMTRC table and time-to-fire on Table VIII Battlesight engagements (the more hits, the more time to fire). This phenomenon is repeated in the moderate relationship between number of Willey BOT hits and time to fire (the more BOT hits, the longer to fire). A moderate negative relationship was found between TCGST and Table VIII score, and a significant positive relation existed between Willey BOT time and success on Battlesight engagements (the faster on BOT, the more successful on Battlesight engagements). Finally, the multiple R between skills tests and time on battlesight engagements proved to be significant. A complete intercorrelation matrix of Gnr's skills test scores, with means and standard deviations, is included in Appendix E.

DRIVER'S APTITUDES AS PREDICTORS

Finally, the zero-order correlations, as well as the multiple R and Wherry-Doolittle R, were calculated for the nine paper-and-pencil tests with the platoon sergeant-platoon leader mean ranking of each driver in their platoon as the criterion. These results are shown in Table 6. Only one correlation was suggestive; the relationship between Lateral Perception and ranking was such that the higher the Lateral Perception score the better the platoon sergeant and platoon leader ranked the drivers on their ability to perform their job. A complete intercorrelation matrix of all Dvr's aptitude test scores, with means and standard deviations, is included in Appendix F.

COMPOSITE SCORES AS PREDICTORS

Following Hughes (1976a & b), two composite scores were derived for each TC and Gnr and entered into a multiple correlation to determine the degree to which they were predictive of the crewmen's primary gunnery

Table 4

THE RELATIONSHIPS BETWEEN GNR'S ABILITY TEST SCORES AND SELECTED MEASURES OF GUNNERY PERFORMANCE

	Table V	Table VIII		
Criterion: / Variable:	1st Rd Hits	Total Score	# Successful BS-S Engagements	Time on[a] BS-S Engagements
Locations	-.31[b]*	-.30[b]*	+.01	+.07
Speed of Perception	+.13	+.09	-.01	-.09
Lateral Perception	-.11[b]	+.17[b]	+.06	+.34[b]**
Visual Recognition	+.35[b]**	-.02	-.00	-.03
Visual Memory	+.06	-.14[b]	+.01	-.05
Object Completion	+.22[b]	+.01	-.10	-.15
Patterns	+.04	-.21	+.06	+.16
Mechanical Abilities	-.09	-.09	-.07	+.04
Attention to Detail	+.18	+10	-.01	-.34[b]**
N =	37	38	38	38
Multiple R	.57	.48	.16	.54
Wherry-Doolittle Shrunken R	.47	.37	.10	.48
(tests)	(4)	(3)	(1)	(2)

* $p < .10$ 2 tailed
** $p < .05$ 2 tailed
*** $p < .01$ 2 tailed

[a] Signs reversed because time and error measures are such that high scores indicate poor performance.
[b] Test selected by Wherry-Doolittle Technique.

Table 5

THE RELATIONSHIPS BETWEEN GNR'S SKILLS TEST SCORES AND SELECTED MEASURES OF GUNNERY PERFORMANCE

	Table V	Table VIII		
Criterion: / Variable:	1st Rd Hits	Total Score	# Successful BS Engagements	Time on[a] BS Engagements
FMTRC Table VII (moving)	+.04	-.06		
FMTRC Table IV (stationary)		+.14	-.30	-.44[b]**
TCGST	-.25[b]	-.33[b]*	-.01	-.13[b]
Willey BOT time[a]	-.01	+.04	+.38[b]**	-.03
Willey BOT hits	-.18[b]	-.13[b]	+.04	-.34[b]*
N =	35	27	27	27
Multiple R	.35	.42	.45	.60**
Wherry-Doolittle Shrunken R (tests)	.29 (2)	.33 (2)	.38 (1)	.55 (3)

* $p < .10$ 2 tailed
** $p < .05$ 2 tailed

[a] Signs reversed because time and error measures are such that high scores indicate poor performance.
[b] Test selected by Wherry-Doolittle technique.

Table 6

THE RELATIONSHIPS BETWEEN DVR'S ABILITY TEST SCORES AND DVR'S RANKINGS

Variable: / Criterion:	Mean Driver Ranking
Locations	-.16
Speed of Perception	+.17
Lateral Perception	+.33[a]*
Visual Recognition	+.10
Visual Memory	+.08
Object Completion	+.19[a]
Patterns	-.26[a]
Mechanical Abilities	+.21
Attention to Detail	-.10[a]
N =	29
R =	.58
Wherry-Doolittle Shrunken R	.44
(tests)	(4)

* $p < .10$ 2 tailed

[a] Test selected by Wherry-Doolittle Technique.

criteria. Two methods were used to compute composite scores, the first based on Hughes' 1976a, and the second based on his revision, Hughes, 1976b. In each case, raw test scores were converted into T-scores, the T-scores multiplied by a weighting based on Hughes' factor analyses, and the products summed to yield composite scores. Computational formulae are shown below:

Method 1
(after Hughes 1976a)

Composite score 1 = .271 x Visual Memory + .398 x Locations + .476 x Patterns

Composite score 2 = .197 x Lateral Perception + .464 x Visual Recognition + .386 x Speed of Perception

Method 2
(after Hughes 1976b)

Composite score 1 = 1 x Locations + 1 x Patterns

Composite score 2 = 1 x Lateral Perception + 1 x Visual Recognition + 1 x Speed of Perception

The only differences between Methods 1 and 2 were unit weighting of tests with Method 2 and the deletion of Visual Memory from Composite Score 1 with Method 2. Because the methods yielded almost identical results, only the results from Method 1 will be reported. These are shown in Table 7 for the primary TC and Gnr criteria. The only relationship approaching significance was between Gnr's composite scores and Table VIII total scores.

DISCUSSION

In this research, paper-and-pencil aptitude instruments and performance on skills tests were used to predict tank gunnery performance and driver rankings. There were four primary objectives, to determine the relationships between TC's and Gnr's gunnery performance and aptitude test scores, skills test scores, and aptitude composite scores, and to determine the relationship between Dvr's aptitude test scores and Dvr rankings. Data collected during the research addressed each of these objectives and is discussed in the following paragraphs.

Table 7

THE RELATIONSHIP BETWEEN TC'S AND GNR'S COMPOSITE SCORES AND MEASURES OF TANK GUNNERY

	TCs (N=42)	
	Table VIII Total	Table VIII Number of successful precision engagements
Composite score 1	+.15	+.25
Composite score 2	-.08	-.08
R	.24	.26

	Gnrs (N=35)	
	Table VIII Total	Table VIII Number of successful battlesight engagements
Composite score 1	-.33*	+.14
Composite score 2	+.06	+.06
R	.36*	.14

* $p < .10$ 2 tailed

Some success was achieved in predicting tank gunnery performance based on TC's aptitude scores. Half the variance in the dependent variable, Number of Successful Precision Engagements, was predicted. This finding is useful in that success on precision engagements is of great importance in successful employment of Armor in both defensive and offensive roles, and in that performance on precision engagements accounts for about half the variance in Total Table VIII scores.

The best single predictor of Number of Successful Precision Engagements was the Object Completion test. This test was designed to determine an individual's ability to detect partially obscured objects, and presumably is related to TC's performance in target identification and ranging. Other measures adding significantly to overall prediction (by Wherry-Doolittle standards) were Visual Recognition, Mechanical Abilities, and Speed of Perception.

The same four tests were selected by the Wherry-Doolittle as predictors of Total Table VIII score, but the degree of prediction was not as great and was of questionable statistical significance. If the total score analysis is thought of as a new, independent analysis, the scores must be considered as only approaching significance: if it is considered a follow-up to the precision-engagement analysis, the result may be interpreted as significant (statistical interpretation is dependent upon the total number of tests considered to be in the battery-9 in the "independent" instance and 4 in the "follow-up" instance). No statistically significant relationships were observed between TC's ability measures and time measures.

When TC's skill's test scores were evaluated, Number of Successful Precision Engagements again could be predicted at better than a chance level. TC's gun laying time was a significant predictor. This may be interpreted to indicate that TC's who can quickly and accurately lay on their targets (the first behavioral requirement in precision engagements) allow themselves and their crews more ample time to engage the targets within the period allotted. Interestingly, however, neither ranging time nor accuracy proved to be a significant predictor of performance.

TC's composite ability scores did not suggest any relationship to gunnery performance; Hughes' findings are therefore not supported in this study wherein his suggestions were extended to TC's in an operational armor battalion.

While some of the criteria of Gnr's performance were significantly related to their ability test scores, the results were not as favorable as with TCs. Visual Recognition again proved to be a significant predictor variable, but only for the Table V (moving target) criterion.

Time spent on battlesight engagements was significantly related to two abilities measures, Lateral Perception and Attention to Detail, but neither of these were significantly related to the other dependent variables. The Location's test was negatively related to performance on both Table V and Table VIII, approaching significance in each case. That result warrants attention in that the two dependent variable measures were completed on different ranges and at different times, separated by about three weeks. Overall, while four aptitude tests (Locations, Lateral Perception, Visual Recognition, and Attention to Detail) show promise for predicting Gnr's performance, the results are clouded by their differing relationship to different measures of performance.

Gunner's skills test scores show the same pattern of significant predictors being related to different gunnery measures. The strongest predictor was performance on the stationary-target FMTRC table. The relationship was such that the more hits on the FMTRC, the more time spent on main-gun Table VIII battlesight engagements. One possible interpretation of this result rests on the fact that the FMTRC was not timed. Slower, methodical firing may have yielded more target hits on FMTRC. The same response trait may then have been carried over to the timed Table VIII where it was reflected in slower times. This result would argue strongly against using FMTRC hit performance (as currently evaluated) for gunner assignment, and suggest timing FMTRC engagements just as in Table VIII.

The same comment can be made about using the TCGST as an assignment device for Gnrs. The negative relation between TCGST performance and Table VIII scores speaks strongly against using the TCGST for selection purposes. Another skills test also merits discussion. Willey BOT time was significantly related to battlesight engagement success. The faster the Gnr's in BOT, the more battlesight success they achieved. The interpretation given the relationship between TC's gun-laying speed and precision engagement success may be used here. Perhaps the faster the Gnr on BOT the more time he has to carefully lay on and engage a target on Table VIII.

Because Gnr's composite ability scores showed only slight, marginally significant relationships with Gnr's performance, the extension of Hughes composites to an operational armor battalion received only very weak support.

Finally we may discuss Dvr's performance rankings and Dvr's aptitude tests. Only Lateral Perception approached significance. It would appear that the aptitude test battery may not be adequate for Dvr performance prediction and/or Dvr performance may be inadequately measured by the platoon leader-platoon sergeant ranking utilized in this study. A behaviorally-anchored dependent variable for Dvr performance would seem to be required in further research on Dvr performance prediction.

This research suggests the following aptitude and skills measures have potential for tank gunnery performance prediction:

PT 2853	Object Completion
PT 5089	Visual Recognition
PT 5088	Lateral Perception
PT 4489	Attention to Detail
PT 3129	Mechanical Abilities
PT 5086	Speed of Perception
	Gun-laying time
	Willey BOT time

These include the 4 paper-and-pencil tests chosen by the Wherry-Doolittle technique as predictors of Table VIII success on stationary precision engagements (for TCs - Table 2), the 2 chosen as predictors of time on stationary battlesight engagements (for Gnrs - Table 4), and the only significant skills-test predictors of successful stationary precision engagements (for TCs - Table 3) and successful stationary battlesight engagements (for Gnrs - Table 5).

The research was limited by the relatively small numbers of TCs, Gnrs, and Dvrs in each analysis compared to the relatively large number of predictor variables utilized--approaching a ratio as low as 1 to 3 in some instances. Good research design, however, would demand a minimum ratio of 1:10 (Kunce, Cook, and Williams, 1975). The results, therefore must be considered as preliminary. Research utilizing an Armor division, with a minimum of 5 armor battalions and 150 available TCs, Gnrs, and Dvrs is strongly suggested. Such research would permit an adequate predictor-subject ratio even with aptitude and skills measures combined in the same analysis, rather than separate analyses as in this research, and would provide more complete answers to questions asked in this research.

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APPENDIXES

APPENDIX A TANK GUNNERY INTERCORRELATION MATRIX, MEANS, AND STANDARD DEVIATIONS

N = 37

	V 1st Rd Hits	V Total	VIII BS Hit	VIII PS Hit	VIII Mov Hit	VIII .50 cal	VIII BS Time	VIII PS Time	VIII Mov Time	VIII Total
V Total	.83									
VIII BS Hit	-.01	-.16								
VIII PS Hit	.14	.17	-.27							
VIII Mov Hit	.05	.07	-.11	.45						
VIII .50	.24	.16	.04	.37	.03					
VIII BS Time	-.25	-.16	-.22	-.18	.02	-.47				
VIII PS Time	.07	-.16	.04	-.09	-.05	-.39	.08			
VIII Mov Time	.03	.11	-.22	.03	-.01	-.21	.27	.13		
VIII Total	.12	.10	.17	.63	.60	.61	-.26	-.31	-.27	
Mean	3.03	7.24	3.38	2.76	1.14	155.16	4.78	11.55	15.97	1524.80
Standard Deviation	1.79	2.81	.76	.89	.63	29.81	1.11	2.26	4.69	207.04

APPENDIX B TANK COMMANDER'S APTITUDE TEST MEANS, STANDARD DEVIATIONS, AND INTERCORRELATION MATRIX

N = 38

	Speed of Perception	Mechanical Abilities	Lateral Perception	Attention to Detail	Visual Recognition	Object Completion	Visual Memory	Locations Test	Patterns Test
Mechanical Abilities	.28								
Lateral Perception	.35	.12							
Attention to Detail	.09	.28	.44						
Visual Recognition	.26	.34	.54	.46					
Object Completion	.55	.38	.44	.34	.59				
Visual Memory	.38	.51	.38	.34	.51	.58			
Locations Test	.13	.24	.16	.14	.22	.19	.17		
Patterns	.24	.13	.49	.28	.34	.57	.41	-.03	
Mean	21.89	37.87	31.92	39.21	30.39	82.03	10.95	22.97	91.16
Standard Deviation	6.86	6.35	6.91	8.71	5.95	11.16	4.17	4.72	1.88

APPENDIX C TANK COMMANDER'S SKILLS TEST MEANS, STANDARD DEVIATIONS, AND INTERCORRELATION MATRIX

N = 40

	Mean Gun Laying Time	Mean Ranging Error	Mean Ranging Time
Mean Ranging Error	.21		
Mean Ranging Time	.48	.09	
Mean	2.45 sec	162.15 ft	3.60 sec
Standard Deviation	.89	117.80	2.08

APPENDIX D GUNNER'S APTITUDE TEST MEANS, STANDARD DEVIATIONS, AND INTERCORRELATION MATRIX

N = 38

	Speed of Perception	Mechanical Abilities	Lateral Perception	Attention to Detail	Visual Recognition	Object Completion	Visual Memory	Locations Test	Patterns Test
Mechanical Abilities	.30								
Lateral Perception	.19	.10							
Attention to Detail	.37	.08	.13						
Visual Recognition	.43	-.05	.24	.44					
Object Completion	.46	.40	.01	.33	.12				
Visual Memory	.37	.32	.35	.21	.32	.20			
Locations Test	.14	.16	-.12	-.16	-.09	.05	.16		
Patterns Test	.28	.27	.14	-.21	.09	-.07	.35	.30	
Mean	20.55	36.58	28.71	38.71	28.89	80.68	10.13	22.07	91.24
Standard Deviation	5.91	7.13	6.69	8.39	5.92	7.70	3.46	4.88	1.85

APPENDIX E GUNNER'S SKILLS TEST MEANS, STANDARD DEVIATIONS, AND INTERCORRELATION MATRIX

N = 24

	Willey BOT Mean Engage-	Willey BOT % Hits	TCGST TC 17-12-5	FMTRC IV % Hits	FMTRC VII % Hits
Wiley BOT # hits	-.09				
TCGST TC 17-12-5	-.26	.14			
FMTRC IV % hits	.32	.00	-.15		
FMTRC VII % hits	-.05	.30	29	.33	
Mean	5.55 sec	80%	195 points	67%	59%
Standard Deviation	1.30	11	25.31	16	21

APPENDIX F DRIVER'S APTITUDE TEST MEANS, STANDARD DEVIATIONS, AND INTERCORRELATION MATRIX

N = 29

	Speed of Perception	Mechanical Abilities	Lateral Perception	Attention to Detail	Visual Recognition	Object Completion	Visual Memory	Locations Test	Patterns Test
Mechanical Abilities	-.08								
Lateral Perception	.15	.45							
Attention to Detail	-.10	-.02	.08						
Visual Recognition	.19	.15	.30	.27					
Object Completion	.10	.26	.22	-.09	.36				
Visual Memory	.32	.30	.09	-.02	.28	.47			
Locations Test	.04	-.05	-.26	-.10	-.07	.17	.43		
Patterns Test	.10	.04	.05	-.27	-.09	.25	.46	.22	
Mean	19.62	33.59	30.55	39.38	28.24	76.31	10.38	21.52	90.72
Standard Deviation	4.98	9.14	5.04	9.81	5.97	11.49	3.63	4.60	4.34